§9. Estimation Method of Impurity Transport by Means of Pulse-Height Analyzer in LHD

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An argon transport depending on magnetic island has been successfully estimated from the experimental results obtained with an assembly of Pulse-Height Analyzers (PHA) in Large Helical Device (LHD). In the present article it is preliminarily reported how diffusion coefficient and convective velocity have been estimated.

The assembly has been constructed to investigate the profiles of the x-ray spectra in the range from 1 to 13 keV.[1] In the present experiment several identical discharges have been performed, while the sight line of the PHA can change to measure the profile of argon K_α line shot by shot.[2]

In the present research the transport of argon particles in LHD plasma has been derived from a continuity equation which is described by

$$-\frac{\partial}{\partial t}n(\vec{r},t)=\nabla\bullet\vec{\Gamma}(\vec{r})\ ,\qquad (1)$$

where $n(r,t)$ and $\Gamma(r)$ are an impurity density and an impurity flux, respectively.[3] It is assumed that the impurity flux is expressed by the summation of a diffusion term and a convective term as follows,

$$\vec{\Gamma}(\vec{r})\equiv -D(\vec{r})\nabla n(\vec{r})+\vec{V}(\vec{r})n(\vec{r})\ ,\qquad (2)$$

where $D(r)$ and $V(r)$ are the diffusion coefficient and the convective velocity, respectively. By making the assumption in the following equation

$$n(\rho,t)=A(\rho)f(t-\phi(\rho))\ ,\qquad (3)$$

it is possible to solve Eq.(1) as follows,

$$D(\rho)=-a^2\left(\rho A(\rho)\frac{\partial\phi(\rho)}{\partial\rho}\right)^{-1}$$

$$\times e^{-\frac{\phi(\rho)}{\tau}}\left[\frac{Y_0}{\tau}+\left(1-\frac{1}{\tau}\phi(\rho)\right)X_0\right],\qquad (4)$$

where a, ρ, $A(\rho)$, $f(t)$, τ, and $\phi(\rho)$ denote an averaged plasma radius, a normalized radial coordinate, the density profile of the impurity, the time evolution of the impurity, the decay time of $f(t)$, and a phase-shift profile which is time necessary for the impurity particles to penetrate to a position of ρ in the plasma. The sign X_0 and Y_0 are defined by

$$X_0\equiv\int_0^{\rho}d\zeta\zeta A(\zeta)e^{-\frac{\phi(\zeta)}{\tau}}\quad \text{, and}\qquad (5)$$

$$Y_0\equiv\int_0^{\rho}d\zeta\zeta\phi(\zeta)A(\zeta)e^{-\frac{\phi(\zeta)}{\tau}}\ ,\qquad (6)$$

respectively. In addition the convective velocity is also solved as,

$$V(\rho)=\frac{1}{a}e^{-2\frac{\phi(\rho)}{\tau}}D(\rho)\frac{\partial}{\partial\rho}\ln A(\rho)$$

$$+\frac{a}{\rho}A(\rho)^{-1}e^{-\frac{\phi(\rho)}{\tau}}\frac{1}{\tau^2}\left[\phi(\rho)X_0-Y_0\right].\qquad (7)$$

Fig.1 shows the measured phase-shift profiles of the argon particles in LHD. The penetration time of the argon particles into the plasma center is approximately 0.15 sec as is shown in the figure. However, the spatial derivative of the phase shift is different between in the island case and no island case.

The estimated diffusion coefficient and the convective velocity are shown in Fig.2. In the region where the normalized radial coordinate is less than 0.6, the diffusion coefficient of the island case seems to be better than that of no island case.

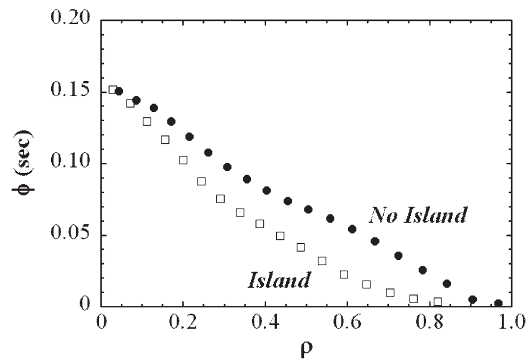

Fig.1. The phase-shift profiles of argon particles measured with the assembly of PHA. The filled circles and the open squares denote the cases of no island and island, respectively. The horizontal axis represents the normalized radial coordinate in the case of no island. The region higher than 0.7 is corresponding to the island. The timing of argon injection is corresponding to ϕ =0 in the vertical axis.

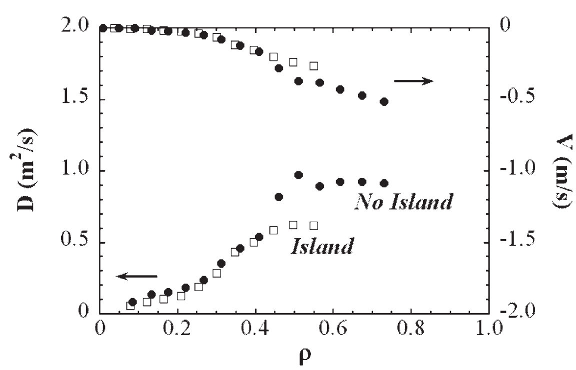

Fig.2. The diffusion coefficients and the convective velocities derived from the measured phase-shift profiles.

References
[1] Muto S., and Morita S., Rev.Sci.Instrum. **72**(2001)1206.
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[3] Takenaga H., *et.al.*, J.Plasma Fus.Res. **75**(1999)952.